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PLANT SUCCESSION ON DUNE SANDS IN FREMONT COUNTY, IDAHO

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Plant Succession on Idaho Dune Sand

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ABSTRACT

Active sand dunes in Fremont County, Idaho, move northeastward approximately 3 m per year. Continuous sand deposits, up to several kilometers long, extend behind the dunes as ridges parallel to the direction of dune migration, with shallower sand between. Pioneer species on the deposits are *Psoralea lanceolata* and *Elymus flavescens*. *Chrysothamnus nauseosus* appears after about 20 years of stabilization, and is followed about 30 years later by *Purshia tridentata*, which remains indefinitely unless disturbed, and by *Artemisia tridentata*, which decreases and largely disappears within 700 years. *Prunus virginiana* var. *demissa* appears in early successional stages. It is densest on old, deep sand where it is codominant with dense *Purshia tridentata*; this community is the most extensive on sand, remains indefinitely unless disturbed, and occupies deposits from approximately 700 to over 4,500 years old. Speciation on old deposits less than 45 cm deep approaches that of the *Artemisia*-bunchgrass type on native soil. Available moisture was lacking in native soil by mid-summer, but was present in dune sand; this probably explains the greater coverage and vigor of shrubs on sand.

INTRODUCTION

The Juniper Buttes area of Fremont County, in southeastern Idaho, has supported a winter big game population for many years. An average of 444 elk, 81 moose, and several hundred deer were counted there each winter from 1949 to 1958 (Idaho Fish and Game Department, 1958). Over 25 km of open sagebrush[2/] separate the area of heaviest winter game concentration from the timbered spring, summer, and fall ranges of the Targhee National Forest.

Key browse species on the game winter range are antelope bitterbrush (Purshia tridentata (Pursh.) D. C.)[3/] and western chokecherry (Prunus virginiana L. var. demissa (Nutt.) Torr.). Western chokecherry commonly grows in hills, mountains, and along streams (Davis, 1952), and seems rather out of place in this semiarid area of typically sagebrush-grass vegetation. Observers prior to this study reported that much of the chokecherry and bitterbrush was growing on stabilized sand, which presumably originated from the active dunes of Fremont County (Fig. 1).

Because the Junipers area is valuable as game winter range, and also as spring-fall domestic sheep range, this study was conducted to determine vegetation-site relationships. The presence of the denser game browse stands on dune sand caused study emphasis to be placed on plant succession on sand deposits. Field work was done in 1958 and 1959. Additional studies will be conducted in the area; these will deal with browse utilization by, and competition between, livestock and big game.

DESCRIPTION OF THE STUDY AREA

Prominent geomorphological features of the study area (Fig. 2) are the Juniper Buttes, sand dunes, and old lava flows which in many places protrude through the thin native soil.

The Juniper Buttes, named for the scattered growth of Rocky Mountain juniper (Juniperus scopulorum Sarg.), are rounded hills which rise a few hundred meters above the surrounding level to gently rolling topography. When viewed from above, the buttes form roughly two sides of an oval, with openings at each end and a basin in the center. Stearns, Bryan, and Crandall (1939) describe them as inliers of the early lava. Structure is complicated, apparently by faulting, but they constitute essentially an arch in the series. They are made up of alternating beds of rhyolite and spherulitic obsidian, capped by a basalt flow which must have originated at about the same time, as it is distinctly older than the basalt surrounding the buttes. Pumice and other pyroclastic materials that characterize acidic volcanoes are absent; hence these buttes were probably not a source of the rhyolite flows. The undrained depression in their midst was caused by eruptions of later basalt on the east and west sides of a narrow valley.

The main belt of sand dunes, located a few kilometers north of St. Anthony, extends from southwest to northeast as a rough crescent about 32 km long and up to 3 km wide. Isolated dune groups, some of which may have broken away from the main belt, are scattered to the north. Some dunes have migrated over the Juniper Buttes. Dunes reach maximum height, about 60 m, near the southwest tip of the main crescent. The dunes consist largely of white quartz sand which presumably originated from lake deposits typically developed near Terreton and the sinks farther west (ibid).

Individual dunes are essentially the barchan type described by Bagnold (1953), although modified in form probably by variable-direction winds and vegetation. Differential melting of snow in the spring may be a factor influencing dune form, as the sand on some parts of a dune is dry and susceptible to wind movement earlier than that on other parts.

A peculiarity of dune deposits in the Junipers area is the formation of sand ridges, one of which typically extends rearward from each leeward tip of a dune. These ridges are mostly parallel, up to 4 or 5 m high, and in some areas they extend for several kilometers in a southwesterly direction. This indicates that winds generally blow from the southwest, causing dunes to migrate to the northeast. Between the ridges are more level, shallower deposits, varying in thickness from a few centimeters to over 4.5 m. The ridges and level deposits are stabilized by vegetation except where disturbed. Native soil and basalt outcrops are exposed in some areas. Sand lost by dunes through deposition apparently is not replaced, indicating that the dunes must decrease in volume as they migrate.

Study was concentrated north of the main belt of dunes, where chokecherry and bitterbrush cover is greatest. Main access through the study area is provided by the Red and Big Grassy Roads, both unpaved and seasonal (Fig. ~~1~~2). The Big Grassy is a local name for grassy openings west of the Juniper Buttes and bounded on the west by an old volcanic crater. The North Dune Area is the name given by the investigator to the dunes and stabilized sand immediately north of the Big Grassy Road and west of the Red Road. The Northwest Dune Area is in the extreme northwestern part of the study area. Dunes and sand deposits east of the Red Road are referred to as the East Dune Area.

Chief obstacles to cultivation in the study area are a lack of water and rocky, often shallow, native soil. Frequent basalt outcrops make operation of equipment difficult. There is no permanent surface water in the study area north of the main belt of dunes. Stockmen truck water to livestock from a few deep wells and from streams outside the area. Several thousand hectares of sand deposits and native soil were plowed and planted to wheat around 1930. Most of these old fields were abandoned soon after, as the rainfall was not enough to support a profitable grain crop. Dryland farming of wheat and various wheatgrasses is still practiced on some of the more tillable native soil. Nearly all the cultivated land south of the main dune belt is irrigated.

The long term mean precipitation recorded at St. Anthony (U. S. Department of Commerce Weather Bureau, 1957) is 34.37 cm per year. The driest months are July and August, which average 1.09 cm and 1.42 cm precipitation respectively.

At the U. S. Sheep Experiment Station near Dubois, Idaho, a few kilometers northwest of the Juniper Buttes, soil moisture at depths greater than 45 cm generally drops below the wilting coefficient by late June or early July (Blaisdell and Mueggler, 1956). Growth of grasses and forbs ceases then, but shrub twigs and flower stalks may grow until early August.

Elevation of the study area, excluding the upper parts of the Buttes themselves, varies from 1,524 m in the southern portion to 1,800 m in the northern and northwestern parts.

NATURE OF THE STUDY

Study emphasis was placed on the status of browse species in the plant successional stages on sand, and on the effect of sand depth and age and soil moisture on these species. Wildfires have been common in the Junipers area; some are accidental and some are set by stockmen in an effort to replace shrubs with grass. The effect of fire on plant communities was observed extensively, to provide a basis for possible future study.

METHODS

SAND AGING

Ability to age successional stages in an ecological study is desirable but seldom possible. Many of the Fremont County dunes have evidently been migrating and continually depositing sand for many years. Assuming a fairly constant migration rate, the age of any deposit whose source dunes are still active can be determined by multiplying the rate of movement by the distance from the dunes. This doubtless involves considerable error, but the relative values should be valid, and the absolute values are useful even though the error is quite large. Sand age will here refer to the calculated time elapsed since the last passage of a dune over the site in question; this also approximates the period of time since stabilization by pioneer vegetation.

Dune movement rates were measured directly by observing the distance traveled by eight dunes of varying size during one year. Paired steel fenceposts, 15.2 m apart, were set at right angles to the dune fronts to allow remeasurement along a constant direction. Comparing the position of various dunes on two sets of aerial photographs taken ten years apart gave an indirect measure of movement rates.

Source dunes for some deposits, as in Sample Area III, Figure 2 ~~1~~, ~~have~~ diminished in size to where they stopped migrating and became stabilized by vegetation. These deposits cannot be aged by applying the rate of dune movement because the length of time since stabilization is not known.

Olson (1958) observed the formation of a bleached A_2 horizon in Lake Michigan dune sand after about 1,000 years of stabilization, when soluble carbonates were leached below the level of most tree roots and were not recycled to the surface. Exploratory measurements in the Fremont County dunes showed surface reaction to be mildly alkaline on young sand and moderately acid on old sand. This indicated the possibility of an orderly pattern of base leaching on stabilized sand. If this pattern exists, and could be established by measuring reaction at constant depths and intervals on deposits behind active dunes, a scale would then be available for comparison with base leaching of unknown-age deposits. This would allow relative age determination of any dune sand.

To study the base leaching pattern on known-age sand deposits, reaction was tested along a sand ridge in Sample Area II to a distance of 8,230 m from the source dune. Testing was done at several constant depths and intervals, and was repeated on adjacent, level, sand sites. Deposits directly northeast of the above dune group and in Sample Area I were tested similarly, to distances of 2,740 and 1,220 m, respectively, behind the source dunes.

Reaction was then measured at similar depths in the unknown-age deposits of Sample Area III, at several intervals starting at the northeast end and continuing to the crater at the southwest end. The northeast end of these deposits marks the point where the source dunes became stabilized, since no sand is found beyond that point, and it is probably safe to assume that the sand here was the most recently deposited.

VEGETATION SAMPLING AND SITE CORRELATION

Preliminary observations indicated that plant communities on stabilized sand are influenced by sand age, depth, and disturbance. In order to compare quantitatively the vegetation and site characteristics in various communities, it was necessary to develop a method to measure these characteristics.

Crown cover was selected as that parameter which would best show the relative influence in the ecosystem of each species in a stand, regardless of life-form. Estimation was chosen over measurement methods because of the large area involved and the time limitation (Brown, 1954). The vegetation sampling technique adopted closely followed that of Daubenmire (1959), with modifications as described.

Twenty vegetation sample units, each consisting of forty 0.1 m^2 canopy-coverage estimate plots, were located selectively on stabilized dune sand. Every distinct vegetation type on sand deposits within the study area was sampled at least once. Multiple samples in some types gave a measure of the effect of sand age and depth variations, and fire. Soil and other site characteristics were recorded at each sample location. The areas which showed the best possibilities for study of succession coincided largely with the area of greatest winter game concentration.

Early successional stages were studied on deposits up to 400 years old in Sample Area I. The sand ridges here are high and steeply sloping, and form barriers to fire and livestock. This was the only sizeable sand area found where vegetation development has been relatively free of disturbance from these factors. The deposits are continuous to about 1.6 km behind the dunes. Ten sample units were located here in pairs, one on level sand and one on adjacent ridge sites of similar age sand.

The second group of six samples was located in Sample Area II. These deposits extend about 7.2 km to the southwest from the source dunes; native soil and basalt are exposed in many places beyond that point. Much of the older sand has been cultivated and abandoned. Sampling emphasis here was on older sand vegetation, fire types, and shallow sand. Time did not permit sampling ridges; these were compared visually to adjacent vegetation on level sand.

The last four samples were scattered over the unknown-age deposits designated Sample Area III. The early successional stages are not present here, which indicates the source dunes have been stabilized for some time. Sampling was done in two old-sand types of different ages, and in disturbance types caused by fire and cultivation.

The following technique was used to describe vegetation and site conditions for each sample unit:

1. The center of the most homogeneous part of the type to be sampled was located subjectively. At this point, the sample center, sand colors and reactions were recorded at set intervals to the bottom of the deposit or to 3 m, whichever was reached first. Underlying native soil profile characteristics were recorded according to the Soil Survey Manual (Soil Survey Staff, 1951) on two shallow sand sites.

2. A 15.24 m tape was stretched from the sample center along a randomly selected compass bearing in each of the four quadrants. Canopy coverage by species and for total vegetation, and percentage cover of litter, rock, and bare ground, was estimated on ten 20 x 50 cm plots equally spaced along each of the four transects. Sand depths at the ends of the transects were recorded. Stakes were left to mark transect locations for remeasurement.

Big sagebrush (*Artemisia tridentata* Nutt.), bitterbrush, and chokecherry were recorded by height class as well as by canopy coverage. One to three representative plants of each were aged when they were found in the sample area.

3. Transects were located systematically on sand ridges. From the sample center on the ridgetop, two 10-plot transects were run in opposite directions along the ridge crest. Two more transects were located at right angles to the first two, from the sample center down the opposing slopes. The lengths of the two latter transects equalled the length of slope; no slope longer than the tape was encountered. The interval between plots was adjusted to allow equal spacing of 10 plots along the shorter transects.

4. Additional information recorded for each sample included slope and exposure, evidence of fire, and a list of species present but not contacted in the plots. Chokecherry was not adequately sampled by the same method used for other vegetation because of its extremely clumped distribution. The relative amount, height, and apparent vigor was therefore recorded for chokecherry when present even though it did not occur in the sample.

One native soil site was sampled as a basis for comparison with sand vegetation. The site chosen represented an average of drainage conditions, had not been recently burned, and had received relatively light grazing use. The soil profile was described at the sample center and the vegetation was sampled similarly to that on level sand. The vegetation and soil profile were examined extensively on other native soil sites throughout the study area.

SAND AND NATIVE SOIL CHARACTERISTICS

Sand and native soil samples were subjected to mechanical analysis by the Bouyoucos hydrometer method (Wilde and Voigt, 1955), and sand samples were sieved to measure grain size.

Available moisture was determined in mid-August. Sand was collected in the North Dune Area at three depths from an active dune supporting a thin sand ryegrass (Elymus flavescens Scribn. and Smith) stand, and from a stabilized deposit covered by chokecherry and bitterbrush. Two nearby native soil sites were tested for comparison. Water held at a force of 15 atmospheres, which approximates the lower limit of moisture available to plants, was measured by a pressure membrane apparatus (U. S. Salinity Laboratory Staff, 1954) and expressed as a percentage of the ovendry weight.

Sand and native soil samples were collected at depths between 2.5 and 5.0 cm from most of the vegetation sample sites and potassium dichromate tests were made for organic matter content (ibid.).

DUNE MOVEMENT AND SAND AGE

The distance traveled in one year by the eight dunes measured directly varied from 0.7 to 5.3 m, for an average rate of 3.5 m per year. Sixteen movement rates were calculated indirectly from aerial photographs; results ranged from 0.5 to 4.8 m per year over the ten year period, for an average 2.5 m per year. The average of these two average rates is 3 m per year, which is the figure used in calculation of sand deposit ages.

The slowest moving dunes were often the tallest. Sand Mountain, about 60 m high, moved only about 0.6 m per year. Movement of dunes topographically sheltered from the wind, such as those that have migrated over the Juniper Buttes, was negligible. Different parts of a given dune were found to move at different rates, indicating the dunes are constantly changing shape.

The smaller dunes in the rear of dune groups often move slowly. Ground examination showed that these are often more stabilized by vegetation than others in the same group. Apparently these dunes, after reduction to some threshold size by deposition loss, slow down and finally stop. They remain as vegetated, crescent-shaped ridges situated transverse to the normal sand ridges.

Reaction testing indicated that the leaching of bases in sand is influenced by other factors besides time and moisture, and is too irregular to permit its use as a basis for aging deposits. Surface pH of the known-age deposits studied in Sample Area II showed considerable variation, but no gradual decrease from young to old sand. Factors such as vegetation, fire, and erosion and deposition by wind doubtless complicate surface carbonate leaching. Surface reaction was generally lower on the level sites than on adjacent ridge crests; more snow generally accumulates in the lower areas, making more water available for leaching. Reactions between 15.2 cm and 1.22 m below the surface in Sample Area II were in the neutral range for all sand ages and for ridges and level sand.

An alkaline layer of pH 8.0 to 8.4, up to 2 m thick, was found below the 1.8 m level on the sand ridge tested in Sample Area II. This layer was first contacted 7,300 m behind the dune, on sand approximately 2,400 years old, and it continued to 8,230 m where testing stopped. A layer of lime accumulation is usually found below 0.5 to 1 m in native soil of the Junipers area, and its presence in stabilized sand whose source dunes contain soluble carbonates (as evidenced by effervescence upon addition of dilute hydrochloric acid) is not surprising. Because of larger pore spaces and greater depth of water percolation, the base accumulation layer is lower and thicker in sand than native soil. The level sand deposits checked in this area were less than 1.8 m in depth, and did not contain an alkaline layer.

Deposits directly northeast of Sample Area II were generally similar in reaction at corresponding depths and ages to those in Area II. Sand older than 900 years there has been overrun by active dunes and could not be tested.

The unknown-age deposits examined in Sample Area III were generally similar in reaction between the surface and the 1.2 m level to the known-age deposits. However, no layer of high pH was found on any of the sites tested. Possibly the sand deposits here are very old, and the soluble carbonates have been leached to below 4.6 m (the maximum depth tested). No dark subsurface layers of high organic content were found, however, nor were there any bleached surface layers of very low pH.

A more plausible explanation is that deposits here were too low in soluble carbonates originally for an alkaline layer to form. That variation in dune carbonate content exists was shown by testing the surface reaction of several widely scattered dunes; pH values varied from 6.6 to 8.5. Dunes farthest to the northeast were generally lowest in pH. Assuming a common place of origin, these have possibly been active and exposed to leaching longer.

The absence of early successional stages in Sample Area III suggests that a few hundred years have elapsed since the causative dunes became stabilized. The time interval is probably not longer than that, as sand ridges in the northeastern end are still quite high and steeply sloping. Ridges in the southwestern part of Area III are so low and gently sloping as to be nearly indiscernible.

For purposes of this study, the stabilized dunes at the northeastern end of Sample Area III will be assigned an age of zero-plus years. It will be assumed that the deposits southwest of and in line with these stabilized dunes were laid down by them, and that the dunes were then migrating at the same rate that others are now. These deposits will be aged using the previously established movement rate of 3 m per year, and a + sign will follow the calculated age. Thus, a site 300 m southwest of the northeastern end of the area will be assigned an age of 100+ years. Deposits near the crater in the Big Grassy would then be 4,500+ years old.

VEGETATION CHARACTERISTICS AND RELATION TO SITE

VEGETATION ON SAND

General.--Continuous sand deposition by active dunes in the study area provides a unique opportunity to study plant succession, in that all the stages are present. The deep sand communities on recent deposits appear as bands of vegetation, transverse to the direction of dune movement, which are distinctly different in aspect. These bands are narrowest on the youngest deposits, and are progressively wider as one proceeds southwest from the causative dunes.

Initial establishment of a species on dune sand in the study area evidently is not dependent on any site improvement as a function of time, such as soil nutrient increase, but rather appears related to such factors as the rate of sand deposition and erosion, seed introduction, germination, survival, and competition. This is indicated by the dense growth of chokecherry, serviceberry (*Amelanchier alnifolia* Nutt.), and snowberry (*Symphoricarpos vaccinioides* Rydb.), on parts of dunes that have migrated over the Juniper Buttes and are now protected from the wind by them. These species typically appear in later successional stages on deposits behind active dunes on level ground (the serviceberry and snowberry in trace amounts only), and their presence here is probably made possible by the stability of the dunes.

Table 1 relates plant canopy coverage and ground surface data from the 20 samples of 40 plots each on sand sites to sand age and depth, and disturbance. Shallow sand, unless otherwise specified, is that less than 45 cm deep. Similar information from the sample on native soil is included for comparison. Coverage figures for chokecherry do not present a true picture of that species because of its clumped distribution. Figure 3 illustrates graphically the relation of canopy coverage of dominant species to sand age on the various sites sampled. Species observed in the study area but not contacted in the samples are listed in Table 2.

Coverage data for dominant species in each level-ground sample, where the transects were stratified-randomly located, were treated statistically to indicate variation and reliability. The mean percentage cover, coefficient of variation, and the standard error of the mean expressed as a percentage of the mean are given in Table 3.

The percentages of bitterbrush, sagebrush, and chokecherry by height class are given in Table 4. Ages, heights, basal diameters, and growth rates for representative shrubs when these species were on a sample site are presented in Table 5. Ages for many of the older bitterbrush plants are probably accurate only to the nearest four or five years, as stem dieback prevented accurate aging.

The following communities or types are named for the dominant perennial shrubs or grasses, except for the pioneer type where a forb is codominant with a grass. Where vegetation on a ridge differs from that on adjacent level sand, the ridge type is not assigned a special name, but the differences are discussed.

Elymus-Psoralea community.--Two samples were located in the pioneer type in Sample Area I, one on level sand and the other on an adjacent ridge. The type here extends to about 60 m behind the rear edge of the active dunes. The pioneer species, sand ryegrass and scurf-pea (*Psoralea lanceolata* Pursh.), are both rhizomatous. Only a trace of other forbs was found; hoary aster (*Aster canescens* Pursh.) and *Eriogonum deflexum* Torr. on the level site, and evening primrose (*Oenothera pallida* Lindl.) and *Eriogonum dendroideum* (Nutt.) St. on the ridge. Bunches of Indian ricegrass (*Oryzopsis hymenoides* (Roem. and Schult.) Ricker.) were scattered throughout the type, although more were found on the ridge. Rubber rabbitbrush (*Chrysothamnus nauseosus* (Pall.) Britt.) was present on the opposite ridge slope from the pioneer type, and had apparently invaded from an adjacent second successional stage.

The pioneer type is characterized by low total vegetation cover, few species, slight litter accumulation, and much bare sand (fig. 4). Sand ryegrass and scurf-pea coverage is quite uniform and the species show a high frequency of occurrence characteristic of rhizomatous plants.

The sample centers were roughly 30 m behind the active dune, indicating a sand age of 10 years. Reaction was high (pH 7.9-8.2) throughout the profile. Sand color was a uniform, moderately dark gray to moderately dark grayish brown. Sand on the ridgetop was over 3 m deep, and was 2.1 m deep on the level sample site.

The pioneer type was found behind every dune, on sand from a few centimeters to several meters deep. The sand ryegrass, and scurf-pea to a lesser extent, grow also on all but the most actively eroding or depositing parts of the dunes. The stand on an active dune is very open, however, and probably offers little protection from the wind. The type may extend a few to over a hundred meters behind a given dune.

The dominant pioneer species are unpalatable to livestock and game animals, and their main value to man is in their stabilizing effect on dune sand. Because of the open growth the type is little affected by fire.

Chrysothamnus-Elymus-Psoralea community.--A pair of samples was located on level sand and an adjacent ridge in the second successional stage in Sample Area I. Rubber rabbitbrush becomes established in quantity from a few to 90 m or more behind the active dunes, where it forms a relatively dense stand with an understory of pioneer species. The transition from the pioneer to the second successional stage is quite abrupt (fig. 5).

Douglas rabbitbrush (Chrysothamnus viscidiflorus (Hook.) Nutt.) also comes in at about the same time, but covers less area than the other rabbitbrush. It is less noticeable because of its lower height. Sand ryegrass was present in about the same amount as in the previous type. Scurf-pea coverage was greater than in the pioneer type, probably because sampling was conducted a week later when the plants had grown larger. Indian ricegrass was again contacted in both samples, although more was found on the ridge. This species seemed to do better throughout the study area on the more open sites. Sand dropseed (Sporobolus cryptandrus (Torr.) A. Gray) occurred in both samples.

More forb species were found in this type than the previous one, although only scurf-pea, and evening primrose on level sand, had over 1 percent cover. Litter cover was much greater than in the pioneer type, and consisted mostly of dead rabbitbrush leaves and twigs. Total vegetal cover was also much higher because of the shrubs present.

Distribution of rubber rabbitbrush was quite uniform. Reliability of the mean for scurf-pea was nearly the same as in the previous sample, but the standard error for sand ryegrass was much higher; this may indicate a decline of the ryegrass, as it was absent in most older undisturbed communities.

Sand age at the sample centers was about 40 years. Depth on the level site varied from 30 to 60 cm. The ridge sand again was over 3 m deep at the top. Since the type was essentially similar on the two sites, sand depth variation, when deeper than 30 cm, apparently has little effect on vegetation in this community.

Color of the ridge sand and the top 15 cm of the level site was similar to that of the previous sample areas. Below 15 cm on the level area, the sand when moist was dark to very dark grayish brown. The dark color probably indicates increased organic matter in a buried sand layer considerably older than the overlying, recently deposited sand. The presence of the assumed older sand surface apparently had little effect on the vegetation, as the same successional stage on other sites of all recent sand appeared no different. Sand reaction again was alkaline, although the surface of the level site had been leached to the neutral range.

Where sampled, the type extends for about 150 m from the rear edge of the pioneer type to the beginning of the next type. In other areas this distance varies from less than 30 m to over 210 m.

Since the second stage is found at a fairly constant distance behind various dunes, rabbitbrush rate of advance must approximate that of the dunes. The rabbitbrush seeds are probably unable to germinate and survive until the pioneers increase to a certain density, with a resultant increase in sand stability.

Because of the palatability of rubber rabbitbrush to sheep and game animals, the type probably has some economic value other than as a sand stabilizer. The total acreage covered is much smaller, however, than that of later successional stages.

Purshia-Chrysothamnus community.--Bitterbrush appears in quantity on stabilized sand after about 50 to 60 years, although scattered shrubs may be found in the two previous types. It replaces much of the rabbitbrush, and forms a distinct type with the surviving rubber rabbitbrush plants that extends for about 150 to 210 m in the area sampled. The leading edge of the community (the edge nearest the rear of the dunes, and parallel to it) is apparently advancing into the rabbitbrush-ryegrass-scurf-pea type at about the same rate that type is proceeding into the pioneer stage, which in turn about equals the rate of dune movement. This suggests that perhaps the rabbitbrush after 40 or 50 years has altered site conditions through further sand stabilization and litter accumulation to a point where bitterbrush seeds can germinate and grow. Once established on sand, bitterbrush remains indefinitely unless killed by fire or other disturbance.

Two samples were located in the bitterbrush-rabbitbrush type in Sample Area I, on sand approximately 80 years old. One was on a level site, and the other on an adjacent ridge. Bitterbrush plants were relatively tall and uniformly distributed. Although rubber rabbitbrush coverage was much lower and more irregular than in the previous type, this shrub was still present in a sufficient amount to be considered a dominant. Douglas rabbitbrush coverage was small on the level, but was greater on the ridge than that of the other rabbitbrush.

Sand ryegrass was missing on the level sample, and only a trace grew on the ridge. This species is generally restricted to exposed openings when present on sand older than about 50 years. Thickspike wheatgrass (Agropyron dasystachyum (Hook.) Scribn.), found only occasionally in the second successional stage, was scattered quite uniformly over both sample sites. The level site supported traces of needle-and-thread (Stipa comata Trin. and Rupr.).

Scurf-pea coverage was only a trace on the level site, but was greater on the more open, exposed ridge. Several other forb species were present in trace amounts, especially on the level sand.

More of the ground was covered by vegetation here than in the previous community. Litter accumulation was considerably higher on the level sand than the ridge.

Sand color on the level was dark to very dark grayish brown when wet, which probably indicates an older exposed sand surface. Significantly, the vegetation here was very similar to that on the lighter colored, apparently more recently deposited ridge sand.

Sand depth varied from 76 to 122 cm on the level site and was over 3 m on the ridge crest. Reaction of the surface level sand was pH 6.2, and was near neutral below 15 cm. The low surface pH would be in agreement with the dark color in indicating an older sand surface. The ridge sand was quite alkaline below 15 cm (pH up to 8.2).

The bitterbrush-rabbitbrush type was found at a similar distance behind most other dunes in other areas examined, although in many cases it had been altered by fire. Vegetation on sand less than approximately 25 cm deep within the type has characteristics of both that on deep sand and native soil. The bitterbrush furnishes forage, although the type is not nearly so extensive as are later deep sand stages, and is not as important economically.

Purshia-Artemisia-(Prunus) community.--Big sagebrush begins growth in Sample Area I at an average distance of about 400 m behind the rear of the active dunes and continues to the southwest as far as the deposits remain contiguous, where the sand is about 500 years old. Chokecherry comes in at about the same time as sagebrush here, although in other areas it may appear much earlier or much later. It may or may not occur in this type, and therefore appears as parenthetical in the community designation. More clumps are on the ridges than on the level deposits. Like bitterbrush, once chokecherry becomes established on dune sand it remains indefinitely unless disturbed.

Four samples were located in this type in Area I; one pair on level sand and an adjacent ridge about 180 years old, and another pair on 400-year-old sand. The older level sample was on shallow sand (25 to 50 cm). A few faintly charred pieces of wood showed the area was burned many years ago, but the type here has probably been less disturbed by fire than anywhere else in the Junipers area. For comparison purposes, this area will be designated as undisturbed, in contrast to other, more recently burned, areas.

Another sample was located in Area II, on level sand about 150 years old (fig. 6). Charred sagebrush stumps indicated a more recent burn than in Area I. The last fire probably occurred over 18 years ago, as evidenced by live sagebrush of that age. No sample was located on the ridge here.

Sagebrush was taller, covered more ground, and grew faster on the recent burn than on the two level undisturbed samples. Over 25 percent of the shrubs contacted were taller than 1.5 m, and individuals 2.4 m high were seen. One over 1.8 m high and 10 cm in basal diameter was only 18 years old. The reason for the greater vigor of sagebrush here compared to native soil sites is not known. Sand depth was between 30 and 35 cm, which is intermediate between that on the two undisturbed level sites.

Only a trace of sagebrush was contacted on the undisturbed ridges. Observations throughout the study area showed the same thing; sagebrush has difficulty growing on the steeper, higher ridges.

Bitterbrush was shorter and covered less ground under the tall sagebrush on the recent burn than on the other four, undisturbed, sites. Total bitterbrush coverage was less on all sites than in the previous community. Standard error of the mean was higher on all three of the level-sand samples than for the previous type, showing that distribution was less uniform.

Chokecherry was present on all four undisturbed sites, although it was not actually contacted in one sample because of its non-uniform distribution. The plants were tallest on the ridges and other relatively deep sand deposits. Plants were scattered and under 1.2 m in height on the shallower of the two undisturbed level samples. This apparent relationship between chokecherry vigor and sand depth was tested extensively throughout the study area. Sand depth was measured under many clumps growing in depressions or other situations where the topography indicated shallow sand. Large bushes over 3 m tall and 10 cm inches in diameter were almost without exception restricted to deposits over 76 cm deep. On shallower sands, the plants were less vigorous, shorter, and less dense. Some small, scattered chokecherry was found on sand as shallow as 45 cm.

Chokecherry was absent from the sample on the burn in Area II, and did not grow on the ridges there either. This species first appears on sand about 900 years old in this area, and from there it grows on deep sand to the southwestern end of the deposits. Chokecherry establishment doubtless depends on chance transportation of the heavy seed, possibly by animals, to a favorable site.

Rubber rabbitbrush was absent from all three level-sand samples, although scattered shrubs were seen in the vicinity of the undisturbed sites where the sand was over approximately 60 cm deep. It was present in some quantity on the ridges. This species never attains the prominence in later stages that it has in the second successional stage, and on old sand is often lacking altogether. It seemingly is restricted to fairly deep sand, whereas the more ubiquitous Douglas rabbitbrush may be found in almost any situation, from native soil to deep sand.

Thickspike wheatgrass was scattered quite uniformly over all five sample units, although total cover was quite low. Needle-and-thread first appeared in quantity in this type, and was present in every sample except one ridge site. Coverage was greatest on the level undisturbed sites. Indian ricegrass was contacted only in the two ridge samples. Other grasses found in small amounts were Junegrass (Koelaria cristata (L.) Pers.), sand dropseed, and Sandberg bluegrass (Poa secunda Presl.).

By far the most important forb on the two undisturbed level sites (fig. 7) was arrowleaf balsamroot (Balsamorhiza sagittata (Pursh) Nutt.). A much smaller amount grew on the ridges, and none occurred in the burn sample. Evidently balsamroot requires a stable situation to grow in quantity. Several other forbs were found in trace amounts in all five samples.

Total vegetation cover was higher on the four undisturbed sites, except for one ridge, than for previous types. It was greater on the level sites than the ridges and the burn. More litter was present on the protected level sites than on the ridges and the burn.

The bitterbrush-sagebrush-(chokecherry) type was found on other stabilized sand also, as behind the eastern group of dunes in the North Dune Area, and in the Northwest Dune Area. In Area II, the community first appears at 70 to 80 years and continues to sand approximately 450 years old. Here small, irregular, grassy openings, composed mostly of needle-and-thread, appear in the sagebrush. Bitterbrush grows around the edges of many of these openings, and apparently spreads. By 700 years, (2100 m southwest of the dunes) very little sagebrush remains on deep sand, and the vegetation is dominantly bitterbrush and chokecherry. This situation predominates for as far as the deposits continue, to the vicinity of Sand Mountain. Sagebrush remains on those sites where the native soil is exposed or close to the surface, and does not attain nearly the height it does on sand over 30 cm deep. Very little sagebrush was found on sand over a thousand years old throughout the study area, which suggests its absence here is part of the natural succession rather than having been caused by disturbance.

A few patches of sagebrush grow on deep sand in the northeastern part of Area III, on and near the old stabilized dunes. This may indicate that only a few hundred years have elapsed since the dunes stopped moving.

The sagebrush-bitterbrush-(chokecherry) type is quite extensive, and the bitterbrush furnishes food for game and livestock where not made unavailable by dense sagebrush. Where it occurs, chokecherry in the type also is important. The grasses and forbs, particularly balsamroot, are valuable sheep forage.

Purshia-Prunus community.--This extensive, valuable type was sampled in four locations: in Area II on sand about 1,000 and 2,100 years old, and in Area III at 800+ and 4,500+ years. All four locations were grazed by sheep but were not burned for many years.

Bitterbrush coverage was lowest and most variable on the youngest site, which might have been caused either by the site age or by greater sheep grazing pressure. Coverage was highest and most uniform on the 2,100-year-old site. The majority of shrubs encountered in all four samples was over 61 cm high. Those on the oldest site were tall and much spread out by layering, with small, grassy openings between.

Chokecherry was present in quantity on all sites. It was not contacted in one of the samples and was present only in trace amounts in another, because of its clumped distribution. The estimated average coverage for the species in this type is between 5 and 20 percent.

A few big sagebrush shrubs were growing on sand near the sample on the 2,100-year-old site. They may have become established from a nearby hillside where much sagebrush was growing on exposed native soil. Evidently this species is able to grow on old sand and is probably prevented from doing so in most areas by competition from other plants.

A trace of rubber rabbitbrush occurred in one of the samples, and the species was not contacted at all in the other three. Small amounts were found on ridges near the three youngest sites, where the bitterbrush stands were a little more open. Bitterbrush and chokecherry stands on the low, gently sloping, sand ridges in the Big Grassy are usually quite dense, and rubber rabbitbrush is practically absent. Douglas rabbitbrush, on the other hand, was present on all four sites.

Needle-and-thread occurred on all four samples and had the highest coverage for grasses in the Area III samples. The greatest coverage was on the oldest site, which quantitatively substantiates the observation that small, grassy openings among shrubs seemed to be more numerous on old sand (fig. 8).

Thickspike wheatgrass was also present in all samples, and was the dominant grass on the Area II sites. Coverage was greatest and most uniform on the 2,100-year-old site.

Sand ryegrass was present on both sites in Area III, and scurf-pea was found on the younger of the Area II sites. These pioneer species were restricted to small openings evidently caused by heavy sheep grazing.

Other grasses present in the type were Indian ricegrass, Sandberg bluegrass, and sand dropseed. A trace of cheatgrass (*Bromus tectorum* L.) occurred on the oldest site.

Pricklypear (*Opuntia* Mill. sp.) occurred in all samples and was the dominant forb in all but one, where scurf-pea had greater coverage. Balsamroot was present on all four sites, but in very small amounts. Its reduced coverage compared to the oldest sand in Area I may be related to the greater disturbance in Areas II and III.

Litter was less on all four samples than all but the youngest of the Area I sites, which probably reflects the effect of disturbance. Total vegetal coverage was quite high on all samples.

Sand depth on all four samples was over 1.2 m, and shallow sand was not a factor affecting vegetation. Reaction values were mostly in the neutral range, with leached layers of pH as low as 5.7 from the surface to minus 7.6 cm. Sand color was quite dark, from dark to very dark grayish brown when wet, to at least 45 cm. The surface was grayer, probably because of leaching.

The bitterbrush-chokecherry type probably covers more ground than any other community on sand deposits in the three areas sampled, which includes much of the present game winter range. It is certainly the most extensive type on sand over about 60 cm deep. It also probably furnishes more game forage per unit area than any other type, and its economic importance is obvious.

Burned Purshia-Prunus community.--Two samples were located in a recent hot burn in the bitterbrush-chokecherry type; one on 1,300-year-old sand in Area II, and another at 1,500+ years in Area III.

Charred bitterbrush stems were still standing on both sites. The burns appear on aerial photographs taken in 1951, but do not show on 1941 photographs. Therefore, the burns were probably between 8 and 18 years old at the time of study. The oldest live bitterbrush shrub aged was 16 years old, which substantiates the calculated age of burn. The sand ages are close enough together that age differences probably do not account for any variations in vegetation.

Dominant species on both sites were Douglas rabbitbrush and scurf-pea. Standard errors for these two species were higher than that of dominants in the undisturbed bitterbrush-chokecherry types sampled.

Small bitterbrush plants were seen on both sites, although none were contacted in one sample. Two that were aged on the older site were 12 and 14 years old, but only about 15 cm tall. Diameter growth rates were lower than most of the other bitterbrush plants aged during the study. This probably indicates that the species has had difficulty becoming re-established after the fire, which may be due to competition from other vegetation or to grazing, or both.

A few older bitterbrush shrubs that evidently survived the fire were growing near both sample sites. Some sprouts from burned plants were seen. Bitterbrush sprouting ability seemed to be variable, even within a small area; this may be related to burn intensity.

Chokecherry was apparently little affected by the fire on both sites. Clumps were large and vigorous, with few fire-killed shrubs. Understory vegetation is usually very sparse in a chokecherry clump, and the lack of fuel would reduce burn intensity. Chokecherry is a prolific sprouter, and the few stems that are killed by fire give rise to many shoots from the root crown.

Thickspike wheatgrass grew on both sites and may have survived the fire. Needle-and-thread was more prevalent on the older sample, where it probably survived the burn rather than having come in afterwards. Sand ryegrass grew on exposed sand on both sites, although it was not contacted in one of the samples. This grass did not seem to grow nearly so many flower heads on old sand as it did in the pioneer succession stage. Other grasses contacted were Indian ricegrass, Sandberg bluegrass, sand dropseed, and a trace of cheatgrass. A trace of threadleaf sedge (_Carex_ _filifolia_ Nutt.) grew on the older site.

Many forbs were present on both sites, although only scurf-pea had any appreciable cover. A small amount of balsamroot was present in one sample, and none in the other.

Total vegetation cover was considerably less than that of the unburned bitterbrush-chokecherry community. Litter was drastically reduced compared to undisturbed sites and older burns, and much bare sand was exposed.

The sand was over 3 m deep at both sample centers. Sand color was moderately grayish brown to dark grayish brown when wet on the younger site, and was browner on the older site.

Surface pH on the younger site was slightly higher (6.6) than on nearby unburned areas. Below the surface the sand was slightly acid, approaching neutral below 1.2 m. A moderately alkaline layer was found below 2.7 m. The older site was in the neutral range below the surface, which had a pH of 6.1. One would expect to find a higher surface reaction following fire, but this may have been obliterated by wind erosion.

Much of the bitterbrush-chokecherry type has been burned in recent years, especially in the northwestern half of the North Dune Area. Vegetation on such burns closely resembles that on the two sites sampled. Douglas rabbitbrush and scurf-pea are usually dominant, although there is considerable variation in their relative coverages.

Bitterbrush will probably return eventually on these burns, as evidenced by the small plants present. Also, probably all the present bitterbrush-chokecherry type in the Junipers area has been burned at least once and has come back. Return of bitterbrush is very slow, however, and a hot burn probably causes the loss of this species to big game and livestock for at least 20 years. There is also the potential danger that sand, when stripped of its plant cover, will again become an active dune.

Artemisia-Purshia-Bunchgrass community.--There is considerable uniformly shallow sand between ridges in the Big Grassy. Such shallow deposits generally support one of two vegetation types, the sagebrush-bitterbrush-bunchgrass community described here, and the bitterbrush-bunchgrass type given in the following section. The main differences in vegetation are the presence or absence of sagebrush and relative coverage of species.

The sample was located on sand approximately 1,800 years old. The site had been burned fairly recently, as many of the charred shrub stems were still standing. Dead stumps of both bitterbrush and sagebrush were present, which indicates the shrub cover was similar before the fire. The burned stumps were larger than the live ones, and the sagebrush was probably taller before the fire. The only reason this type was not considered a variation of the previously described bitterbrush-sagebrush-(chokecherry) community was a marked difference in grass species.

Bitterbrush coverage was less than that of sagebrush, and both species were non-uniformly distributed and shorter than on deep sand. Douglas rabbitbrush was also present.

Needle-and-thread coverage was nearly as much as that of sagebrush and was more uniform. Traces of thickspike wheatgrass, Sandberg bluegrass, and Junegrass were also present.

The grass species which distinguish this community from any previously described sand types are Idaho fescue (Festuca idahoensis Elmer.) and bluebunch wheatgrass (Agropyron spicatum (Pursh) Scribn. and Smith.), which covered 9 and 8 percent, respectively, of the sample. These grasses are common on native soil but do not normally grow on deep sand. A possible explanation is that the species which grow so dense on deep sand, namely bitterbrush and needle-and-thread, are more open growing where the sand is shallow, which reduces competition for other species.

Only four forbs were present, and only pricklypear amounted to more than a trace. Total vegetal cover was somewhat lower than that of undisturbed deep sand types. The comparatively low amount of litter can probably be attributed to the fire.

Sand at the sample center was 30 cm deep, the last 10 cm being a zone of mixing with the native soil, as evidenced by a dark grayish brown color and increased structural development. Reaction was slightly acid on the surface and neutral below. The buried A horizon was 13 cm thick, loamy sand, with medium weak prismatic to coarse moderate sub-angular blocky structure. Below this was a weakly cemented lime hardpan of pH 8.0. The zone of lime accumulation was closer to the surface of the native soil here than in any other native soil profile examined, and occurred at a depth normally occupied by the B_1 horizon.

Near the sample location, and adjacent to the type examined, was a low, gently-sloping ridge where the sand was over 1.2 m deep. Here the vegetation was the bitterbrush-chokecherry type with practically no sagebrush, Idaho fescue, or bluebunch wheatgrass, and was much denser. This held true on other sand ridges in the vicinity, indicating the sagebrush-bitterbrush, bunchgrass type is a function of shallow sand. It is quite common in the Big Grassy area, especially in Area II, on sand from a few to 30 cm deep.

Purshia-Bunchgrass community.--The sample in this type was located a thousand yards southwest of that in the previous community, on sand about 2,100 years old. It is doubtful whether this relatively slight age difference would account for any of the variation in vegetation. The area appeared to have been burned at the same time as the previous one. The largest shrub aged on the site was 15 years old, and the largest one aged in the previous community was 14 years; this indicates the burn probably occurred over 16 years ago.

No live sagebrush plants were present in the area, and none of the burned stumps examined were sagebrush. Judging from the scattered, burned bitterbrush stems, shrub cover was probably similar before the fire.

Bitterbrush covered 26 percent of the sample and appeared more uniformly distributed than would be indicated by the fairly high standard error. Many of the shrubs were over 61 cm high, and several young plants occurred in the plots. Other shrubs on the site were small amounts of Douglas rabbitbrush and horsebrush (*Tetradymia canescens* DC.).

Needle-and-thread coverage was a great deal more than in the previous type. Distribution was very uniform. Idaho fescue and bluebunch wheatgrass were present in about the same amount as in the sagebrush-bitterbrush-bunchgrass type. Other grasses were small amounts of thickspike wheatgrass, Junegrass, and Sandberg bluegrass.

Over twice as many species of forbs were present as were in the other shallow sand type. Of these, balsamroot and Opuntia were most common.

Total vegetation and litter coverage were both greater than in the previous type. This site seemed to be the more productive of the two, which may be related to the slightly greater sand depth.

Sand depth was about 36 cm at the sample center, and pH increased from slightly acid at the surface to mildly alkaline below. The buried native soil A_1 horizon was 10 cm thick, and was similar to that in the previous community. Below this, however, were B_1 and B_2 horizons 10 cm and 53 cm thick, respectively. Structure graded from medium, moderately distinct platy in the B_1 to moderately distinct prismatic to medium, moderately distinct angular blocky in the B_2 horizon. The C_{ca} horizon of lime accumulation began 73 cm below the buried native soil surface, which is typical of native soil in the study area, and continued to the bottom of the profile pit.

A low ridge of deeper sand adjacent to this type supported a bitterbrush-chokecherry vegetation. Denser bitterbrush here, and the absence of Idaho fescue or bluebunch wheatgrass indicates that the bitterbrush-bunchgrass type is a product of shallow sand. The community is very common throughout the Big Grassy, and appears more prevalent than the sagebrush-bitterbrush-bunchgrass type, especially on the older sand of Area III.

The bitterbrush-bunchgrass type was generally restricted to sand between 30 and 60 cm deep, although it was found on sand up to 90 cm deep on one 4,000-year-old site in the Big Grassy. Here Idaho fescue and bluebunch wheatgrass had gained a foothold in the shrub interspaces normally dominated by needle-and-thread. Spikefesuce (*Hesperochloa kingii* (S. Wats.) Rydb.) was present in the type on old shallow sand in one location.

Old field Bunchgrass community.--One sample was located in an abandoned field on sand 4,000+ years old. A few bitterbrush shrubs were scattered over the sample area, and a few were contacted in the plots. The oldest shrub aged was 23 years, indicating that cultivation probably ceased prior to 1935. Although Idaho fescue and bluebunch wheatgrass were present in an adjacent bitterbrush-bunchgrass type, they were not found in the old field type.

By far the most dominant species was needle-and-thread, which covered 71 percent of the sample. Distribution was more uniform than that of any other species in any of the other types examined; the standard error was only 3 percent of the mean. Other grasses present were small amounts of Sandberg bluegrass and cheatgrass, and traces of sixweeks fescue (Festuca octoflora Walt.) and an annual barley (Hordeum Lips.). Threadleaf sedge was also present.

A trace of sand ryegrass was contacted in the sample. Concentrations of this grass were seen on the small blowouts that are quite common in the old fields. Few forbs were present, and only pricklypear amounted to more than a trace.

Sand depth at the sample center was 25 cm. Color at the surface was very dark gray when wet, and very dark grayish brown below. The surface was leached to pH 6.1, and reaction below that was in the neutral range. The buried native soil was not examined.

Sand depth on other parts of the field sampled, and other fields, varied from less than 30 cm to over 1.5 m. Vegetation on the deeper sites was similar to that sampled, indicating this community is not a function of shallow sand. Isolated chokecherry shrubs often grow in the fields on the deeper sand; these were evidently spared when the rest of the ground was plowed.

Boundaries of many of the grassy fields appear on aerial photographs as straight lines with right angle bends, which is quite conclusive evidence of previous cultivation. Boundaries of similar grass stands in other parts of the Big Grassy, however, are not as regular, and the question arose as to whether these were also caused by cultivation or whether they represent a natural stage in the succession. Vegetation adjacent to these grass stands, on sand of similar depths, was either bitterbrush-bunchgrass or bitterbrush-chokecherry, depending on the sand depth. This indicates that the grass types were caused by disturbance, probably cultivation, and that the original vegetation resembled that present on adjacent sand of similar depth. The irregular borders could have been caused by irregular plowing, or perhaps the fields have been abandoned long enough that shrubs have become re-established around the edges and mask the original field border. Present evidence then indicates that the large grass stands, mostly needle-and-thread, from which the Big Grassy derives its name, were caused by cultivation and subsequent abandonment. Why such sites would so greatly favor needle-and-thread over other species is not known.

VEGETATION ON NATIVE SOIL

Big sagebrush was the dominant species on the native soil site. It was all under 1.5 m in height, and its rate of growth was less than half that of the most vigorous sagebrush on sand.

Bitterbrush coverage was only 10 percent, less than a fifth of that in deep sand types. Height growth was not found to be less than on sand, but individual shrubs were not spread out by layering.

Three-tip sagebrush (Artemisia tridentata ssp. trifida (Nutt.) Hall and Clem.) grew in small amounts on the sample site. Although common on native soil, only one shrub of this species was found on sand more than 10 cm deep during the entire study. Its presence in a sand area, in fact, proved to be a reliable indicator of exposed native soil or very shallow sand.

The only other shrub contacted in the sample was a trace of the ever-present Douglas rabbitbrush. Rubber rabbitbrush was not seen on native soil. A small amount of horsebrush was present, although not contacted.

Dominant grasses were needle-and-thread and bluebunch wheatgrass. Idaho fescue was not present, although it was very common elsewhere in similar communities on native soil. Threadleaf sedge was common, although total coverage was low because of the small size of the plant. Trace grasses were thickspike wheatgrass, Junegrass, Sandberg bluegrass, and cheatgrass.

Not as many forbs were found here as in the older sand communities. This may be partly because sampling on native soil was conducted last, in early August, and many of the small forbs were already dried beyond recognition. The most abundant forb was an unknown vetch (Astragalus L. sp.).

The total coverages of vegetation and litter were somewhat less than on the older, least disturbed, deep sand types.

Characteristics of the soil profile, including moist soil colors, were as follows:

Horizon	Depth	Description
A_1	0-10 cm	Loamy sand. Very dark brown at surface, very dark grayish brown below. pH 5.8 at surface, 6.5 below. Structure medium, weak to moderate, sub-angular blocky, to granular. Consistence non-sticky, non-plastic when wet. Boundary gradual.
A_3	10-18 cm	Loamy sand. Very dark grayish brown. pH 6.6. Structure medium, weak angular blocky. Consistence non-sticky, slightly plastic when wet. Boundary clear.
B_1	18-25 cm	Sandy loam. Very dark brown. pH 6.6. Structure medium, weak prismatic to medium, weak angular blocky. Consistence slightly sticky, slightly plastic when wet. Dry, hard. A few clay skins on peds. Boundary gradual.
B_2	25-56 cm	Sandy loam. Very dark brown. pH 6.6. Structure medium, weak prismatic to medium, moderately distinct angular blocky. Consistence slightly sticky, plastic when wet. Dry, hard. Moderate clay skins on peds. Boundary gradual.

Horizon	Depth	Description
B_3	56-71 cm	Sandy loam. Very dark brown. pH 6.9. Structure medium, weak, angular blocky. Consistence sticky, plastic when wet. Dry, hard. Moderate clay skins on peds. Numerous basalt cobbles with lime splotches. Sand grains on fracture surfaces. Boundary gradual.
C	71-114+ cm	Sand. Dark brown to dark yellowish brown. pH 7.0. Structure coarse, weak, sub-angular blocky to single grain. Consistence non-sticky, non-plastic when wet.

The sand below the B horizon probably accounts for the lack of lime accumulation; water is able to leach carbonates to a greater depth than is the case where finer texture continues throughout the profile. Drilling auger holes on two sites about 21 m from the sample center showed a typical lime layer below 61 cm. There was no apparent difference in vegetation between these sites and the one sampled.

Although chokecherry was not present on the sample site, it does occur occasionally on native soil. Growth here seems restricted to cracks in the basalt rock, which probably hold more snowmelt water and impede evaporation more than the surrounding soil. Chokecherry coverage on native soil is very small compared to that on old, stabilized, deep sand.

The two factors which seem to cause most of the local variations in vegetation on native soil in the Junipers area are drainage and disturbance. Probably the most important disturbance has been fire; all the native soil sites examined during the course of the study showed evidence of having been burned. The effect of uncontrolled fires on the vegetation has been quite variable. In some cases the sagebrush was greatly reduced and perennial grasses increased. In other cases the sagebrush has grown back seemingly denser than before. Generally speaking, livestock grazing pressure was seen to be heavy only in localized areas used as sheep bedgrounds.

Although total local relief is less than 15 m over most of the area, except for the Juniper Buttes themselves, the topography is quite irregular because of the numerous basalt outcrops. The local topographic extremes are represented by the rapidly drained outcrops and ledges, and the undrained depressions between. The sample was located on a site intermediate between the two extreme drainage conditions.

Vegetation on most of the well drained sites resembles that described in the sample, with variations caused by fire. Big sagebrush is usually dominant, with lesser amounts of threetip sagebrush and bitterbrush. Dominant grasses are usually needle-and-thread, bluebunch wheatgrass, and Idaho fescue. Soils generally are similar to that described in the sample, except for the sand layer. A layer of lime concentration, such as that found in the native soil beneath the two shallow sand sites described previously, is usually present below 60 to 90 cm. Soil on basalt outcrops may be very thin or absent. Most of the better drained soils are probably chernozems.

Threetip sagebrush generally is the dominant species in depressions, often to the exclusion of big sagebrush and bitterbrush. Examination of the soil profile on one such poorly drained site, where water was ponded during the spring runoff, disclosed a well developed prismatic structure throughout the B horizon, with heavy clay skin development. No sand layer was present, and a lime layer was not contacted. This probably indicates that the increased water present on the site had leached carbonates at least below 137 cm, which was the depth of the profile pit. The soil here was probably a prairie type in a chernozem region.

Vegetation on exposed native soil within sand deposition areas is generally similar to that on nearby native soil sites which have not been covered by sand.

SAND AND NATIVE SOIL CHARACTERISTICS

Table 6 gives the results of the mechanical analysis of sand and native soil, and the sand grain size tests. The sands, as would be expected, were uniformly low in silt and clay. Silt and clay percentages were greater below the 30 cm level in native soil than nearer the surface. Sand grain sizes were quite uniform at the three depths tested. The sand of Area III was finer than that of Area II, which might indicate that it traveled farther from its place of origin, giving the larger particles a longer time to be deposited. The surface sand from these two areas contained more very fine particles than that at lower depths, which probably was caused by presence of fine organic particles and wind-deposited dust. Sand particles from the Northwest Dune Area were all under 0.25 mm in diameter, which suggests a great deal of wind sorting. Possibly these dunes have traveled a greater distance than others in Fremont County.

Total, unavailable, and available moisture are compared between sand and native soil in Table 7. Moisture in all cases is expressed as a percentage of the ovendry weight of the soil. Unavailable moisture (that held by a tension of at least 15 atmospheres) was the same for the two sand sites in the North Dune Area. The fine Northwest Dune Area sand held 1.5 percent as unavailable, compared to 1.2 percent for the other two sand sites. The greatest amount of total and unavailable moisture in sand was at the 91 cm level on the active dune; shrubs present on the stabilized sand probably utilize much of the available moisture.

A sand layer was contacted at the 91 cm level on one of the native soil sites, which had more total and unavailable water than the dune sands; this probably indicates a higher percentage of silt and clay in sand under native soil. A typical lime layer was present at the 91 cm level on the other native soil site.

Total moisture present during the dry season, when testing took place, was greater in every instance for the native soil than for sand. However, all the water present in the native soil was held by a force of at least 15 atmospheres, leaving none available to plants. Although the percentage of total moisture was lower in sand, the unavailable fraction was lower yet, and some water was available to plants in every one of the six sand samples tested. This fact alone may account for the greater vegetation growth, and the presence of chokecherry and dense bitterbrush, on the stabilized dune sand.

Organic matter contents for sands and one native soil site are given in Table 8. The two active dunes were very low in organic matter. Other sand sites, with three exceptions, had similar organic contents of approximately 3 percent. That of the undisturbed ridge was lower, probably because some of the surface sand had been blown or washed away. The 150-year-old site had a higher content than all the others. The explanation probably is that previous burning of the dense, tall sagebrush had increased the organic carbon. The reasons for the low organic content on the oldest sand site is not known, but the area may have been wind eroded. Native soil contained about 7 percent organic matter, which is higher than that of most of the sand sites.

SUMMARY

The Juniper Buttes area of Fremont County, Idaho, is economically important as a spring-fall domestic sheep range, and as a winter range for moose, elk, and deer. Because most of the desirable browse plants are on stabilized dune-deposited sand, a study of sand vegetation-site relationships was conducted as a basis for planning management and further study.

Active dunes in the study area are advancing northeastward approximately 3 m per year. As they move, deposits are laid down in the form of sand ridges, one of which extends rearward from each leeward tip of the dune. The ridges are parallel, and may extend unbroken for several kilometers. More level, shallower sand is deposited between the ridges.

Plant successional stages on the deposited sand appear as vegetational belts, distinct in aspect and dominant species, located transverse to the direction of dune movement.

The belt of pioneer vegetation on the most recently deposited sand behind the active dunes is the most narrow; the width is progressively greater for each succeeding successional stage.

Early types are not static, but advance in the direction of dune movement at a rate approximately equal to that of the dunes. Each apparently requires site preparation by the previous community, which involves a fairly constant period of time. Establishment of a species on sand evidently depends on relative site stability, availability of seed, proper germination conditions, and ability to compete with other plants, rather than on any soil nutrient improvement caused by previous vegetation.

The main pioneer species are scurf-pea and sand ryegrass. After 20 years or so of sand stabilization, rubber rabbitbrush becomes established to form a second successional stage with the pioneer species. Bitterbrush appears in quantity at about 50 years, replaces some of the rabbitbrush, and remains indefinitely unless disturbed. The rubber rabbitbrush decreases rapidly and very little is found on old sand.

Big sagebrush replaces some of the bitterbrush on level sand about 100 years old and disappears a few hundred years later; very little was found on sand after 700 years. Sagebrush size and vigor is much greater on sand than native soil.

The next type, dominated by clumps of chokecherry and dense bitterbrush, is the most extensive and furnishes the most game forage. Chokecherry often appears in earlier stages as well, and its time of appearance on dune sand is more variable than that of other species. Like bitterbrush, once chokecherry becomes established it remains indefinitely unless disturbed. Bitterbrush on very old sand (4,500+ years) is more open growing, and individual plants are much spread out by layering. Needle-and-thread occupies shrub interspaces on old sites.

Sand depth influences vegetation growth, expecially in the older communities. Chokecherry and dense bitterbrush grow mainly on sand over 60 cm deep. At depths between 30 and 60 cm the bitterbrush is more open growing, with interspaces occupied by bunchgrasses common to native soil. Sagebrush grows with bitterbrush and bunchgrass on old sand under 30 cm deep; vegetation here approaches that on native soil.

Cultivated fields on old sand, abandoned over 20 years previously, are covered by dense needle-and-thread grass stands. Bitterbrush is becoming established in some of the old fields and may eventually increase to become dominant.

Fire is probably the worst enemy of bitterbrush on sand. A hot burn will kill most of the plants, and they are very slow to become reestablished. Also, removal of the plant cover exposes the sand to wind action.

Vegetation on native soil in the study area is dominated by big and threetip sagebrush; the latter almost never occurs on sand over a few centimeters deep. Bitterbrush cover is much less than on sand. Chokecherry is mostly restricted to cracks in the basalt rock. Bunchgrasses common on native soil but not on deep sand deposits are Idaho fescue and bluebunch wheatgrass.

Moisture available to plants was absent in native soil by mid-summer, but was present in dune sand below 30 cm. This probably accounts for the greater browse coverage on sand.

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FOOTNOTES

[1] Present address: Rocky Mountain Forest and Range Experiment Station, 282 Agriculture Building, Arizona State University, Tempe, Arizona. This paper is based on a thesis presented in partial fulfillment of the requirements for the degree of Master of Science in Forestry at the University of Idaho, Moscow, Idaho. Study was supported by the Idaho Cooperative Wildlife Research Unit, with the University of Idaho, the Idaho Department of Fish and Game, the U. S. Fish and Wildlife Service, and the Wildlife Management Institute cooperating.

[2] Measurements were originally expressed by the English system, and were converted to their metric equivalents for this paper.

[3] All scientific names for forbs, shrubs, and sedges in this paper follow Davis (1952); authority for grasses is Hitchcock (1950).

Table 1.--Relation of percentage canopy cover of vegetation on level sand and ridges to sand age[1], sand depth, and disturbance. Data from a native soil site is included for comparison.

Site characteristics	Undisturbed, level, deep sand					Undisturbed sand ridges					Old burn, level, deep sand					Old burn, level, shallow sand		Recent burn, level, deep sand		Old field	Native soil
Sand age (years)	10	40	80	180	400	10	40	80	180	400	150	800+	1M	2.1M	4.5M+	1.8M	2.1M	1.3M	1.5M+	4M+	None
SHRUBS:																					
Amelanchier alnifolia			Tr*	*	3										Tr*						
Artemisia tridentata				19	5				Tr		31					25					23
Artemisia tripartita																					3
Chrysothamnus nauseosus	Tr	37	9	*		9	29	8	15	12				Tr							
Chrysothamnus viscidiflorus		5	2	3	1		10	14	17	8	11	15	9	15	12	5	2	22	18	Tr	Tr
Prunus virginiana var. demissa				1	8				*	6		15	Tr	4	*			*	*		
Purshia tridentata			58	36	32			56	30	40	23	43	58	67	55	10	26	*	Tr	3	10
Ribes aureum														2	2						
Tetradymia canescens		Tr*											Tr*		Tr*		2			Tr*	*

Table 1.--continued

Site characteristics	Undisturbed, level, deep sand					Undisturbed sand ridges					Old burn, level, deep sand					Old burn, level, shallow sand		Recent burn, level, deep sand		Old field	Native soil
Sand age (years)	10	40	80	180	400	10	40	80	180	400	150	800+	1M	2.1M	4.5M+	1.8M	2.1M	1.3M	1.5M+	4M+	None
GRASSES AND SEDGES:																					
Agropyron dasystachyum		Tr*	8	3	2			3	9	3	2	3	6	16	2	Tr	2	9	2	Tr	Tr
Agropyron spicatum																8	8				10
Bromus tectorum															Tr				Tr	2	Tr
Carex douglasii																			Tr	3	4
Elymus flavescens	6	7				4	2	Tr				4			3				4	Tr	
Festuca idahoensis																9	7				
Festuca octoflora																				Tr	
Hordeum sp.																				Tr	
Koeleria cristata					3											Tr	Tr				Tr
Oryzopsis hymenoides	Tr	Tr				6	2	Tr*	11	Tr		2	Tr	Tr	Tr			7	2		
Poa secunda				2	1						Tr	Tr	Tr		2	Tr	Tr	*	1	2	Tr
Sporobolus cryptandrus		Tr	Tr*				1	Tr*	Tr*	1	Tr	Tr	2					4	Tr		
Stipa comata			Tr	7	12				2		2	8	2	3	14	20	57	2	14	71	15

Table 1.--continued

Site characteristics	Undisturbed, level, deep sand					Undisturbed sand ridges					Old burn, level, deep sand					Old burn, level, shallow sand		Recent burn, level, deep sand		Old field	Native soil
Sand age (years)	10	40	80	180	400	10	40	80	180	400	150	800+	1M	2.1M	4.5M+	1.8M	2.1M	1.3M	1.5M+	4M+	None
FORBS:																					
Agoseris sp.				Tr																	
Antennaria dimorpha											Tr										1
Aster canescens	Tr						Tr				Tr										
Astragalus sp.																					7
Balsamorhiza sagittata			Tr	39	55				2	6		1	Tr	Tr	2	Tr	4	*	1		
Chenopodium sp.			Tr		Tr					Tr	Tr	2	2	1	2		Tr	4	Tr	Tr	
Comandra pallida				Tr						1	Tr*	Tr					Tr	Tr	Tr		
Cordylanthus ramosus																					Tr
Crepis acuminata				Tr*	Tr																
Eriogonum deflexum	Tr				Tr					Tr		1	Tr	Tr	Tr			Tr	Tr		

Table 1.--continued

Site characteristics	Undisturbed, level, deep sand					Undisturbed sand ridges					Old burn, level, deep sand					Old burn, level, shallow sand		Recent burn, level, deep sand		Old field	Native soil
Sand age (years)	10	40	80	180	400	10	40	80	180	400	150	800+	1M	2.1M	4.5M+	1.8M	2.1M	1.3M	1.5M+	4M+	None
FORBS:																					
Eriogonum dendroideum			Tr	Tr		Tr	Tr				Tr										
Eriogonum heracleoides				*	6										Tr	Tr	Tr			Tr	*
Eriogonum ovalifolium				Tr					Tr		Tr	Tr	Tr						Tr		
Erysimum capitatum			Tr*					Tr	Tr												
Franseria acanthicarpa													Tr					2	Tr*		
Fritillaria atropurpurea														Tr							
Gayophytum nuttallii				Tr			Tr		Tr		Tr								Tr		
Gayophytum ramosissimum															Tr				Tr		
Hackelia patens					1									Tr			Tr				Tr
Lappula sp.				Tr							Tr		Tr*	Tr*	1		Tr*	Tr	1	Tr	

Table 1.--continued

Site characteristics	Undisturbed, level, deep sand					Undisturbed sand ridges					Old burn, level, deep sand					Old burn, level, shallow sand		Recent burn, level, deep sand		Old field	Native soil
Sand age (years)	10	40	80	180	400	10	40	80	180	400	150	800+	1M	2.1M	4.5M+	1.8M	2.1M	1.3M	1.5M+	4M+	None
FORBS:																					
Lithospermum ruderale					Tr																
Lomatium (dissectum?)					Tr					1								Tr*			
Lupinus sp.				Tr													Tr*			Tr	
Lygodesmia grandiflora		Tr																			
Mentzelia albicaulis														1	Tr		Tr	Tr*			
Oenothera pallida		7	Tr			Tr	Tr			Tr	Tr		Tr	2	Tr*			Tr	Tr		
Opuntia sp.			Tr	Tr	Tr			Tr*				Tr	3	5	6	1	4	Tr	1	2	
Phacelia leucophylla		Tr	Tr	Tr*							Tr*	Tr*	Tr	Tr*	Tr*				Tr*		
Polygonum douglasii												Tr			Tr	Tr	2		Tr		1
Psoralea lanceolata	11	23	Tr			7	9	7	16	8	*	8	Tr					19	24		

Table 1.--continued

Site characteristics	Undisturbed, level, deep sand					Undisturbed sand ridges					Old burn, level, deep sand					Old burn, level, shallow sand		Recent burn, level, deep sand		Old field	Native soil
Sand age (years)	10	40	80	180	400	10	40	80	180	400	150	800+	1M	2.1M	4.5M+	1.8M	2.1M	1.3M	1.5M+	4M+	None
FORBS:																					
Rumex venosus									2												
Sisymbrium altissimum					Tr*				Tr		Tr			2	2		Tr	Tr	1		
Thelypodium laciniatum					Tr																
Tragopogon sp.		Tr			Tr										Tr*		Tr			Tr	
ALL LIVE VEGETATION	17	59	69	82	90	25	43	75	76	66	58	82	70	88	83	73	89	58	66	75	71
BARE GROUND	66	13	2	7	4	68	57	14	32	23	25	24	19	5	19	27	10	54	46	24	26
LITTER	6	76	81	82	90	3	22	58	59	76	71	72	73	92	79	60	69	37	50	54	70

1/ Age of sand sites in Sample Area III indicated by +

Tr indicates trace, under 1 percent cover

* indicates species present on site but not contacted in sample

Table 2.--Plants collected which did not occur in samples

Species	Where collected
Abronia mellifera	sand
Agastache urticifolia	sand
Allium acuminatum	native soil
Amsinckia sp.	sand
Antennaria rosea	native soil
Castilleja longispica	shallow sand
Chaenactis douglasii	sand, native soil
Coldenia nuttallii	sand
Cryptantha circumscissa	sand
Delphinium andersoni	sand
Descurainia pinnata	sand
Descurainia sophia	native soil
Elymus cinereus	native soil
Erigeron pumilus	native soil
Eriogonum microthecum	native soil
Fritillaria pudica	sand
Geranium nervosum	native soil
Gilia leptomeria	sand
Haplopappus nanus	basalt outcrop
Hesperochloa kingii	sand
Juniperus scopulorum	native soil

Table 2.--continued

Species	Where collected
Leptodactylon pungens	basalt outcrop
Lithophragma tenellum	native soil
Lomatium triternatum	sand, native soil
Lygodesmia juncea	sand
Mimulus nanus	sand
Monolepis nuttalliana	native soil
Oenothera caespitosa	basalt outcrop
Phacelia ivesiana	sand
Phlox longifolia	native soil
Rosa woodsii	sand
Rumex paucifolius	native soil
Salsola kali var. tenuifolia	sand, native soil
Sphaeralcea munroana	basalt outcrop
Stipa lettermani	native soil
Symphoricarpos vaccinioides	sand
Viola vallicola	sand

Table 3.--*Variability and reliability of mean percentage crown cover for dominant species*[1]

Sand[2] age (yrs.)	Vegetation types and species	Cover (%)	V (%)	SE (%)	SE/$\bar{x}$ (%)	Remarks
10	*El*.-*Psor*.					Undisturbed
	El. *flav*.	6	98	0.9	15	
	Psor. *lan*.	11	91	1.6	14	
40	*Chry*.-*El*.-*Psor*.					Undisturbed
	Chry. *naus*.	37	90	5.3	14	
	El. *flav*.	7	159	1.7	24	
	Psor. *lan*.	23	83	3.1	13	
80	*Pur*.-*Chry*.					Undisturbed
	Pur. *trid*.	58	67	6.3	11	
	Chry. *naus*.	9	248	3.6	40	
	Ag. *das*.	8	135	1.8	22	
150	*Pur*.-*Art*.-(*Prun*.)					Old burn
	Pur. *trid*.	23	142	5.2	23	
	Art. *trid*.	31	127	6.4	21	
180	*Pur*.-*Art*.-(*Prun*.)					Undisturbed
	Pur. *trid*.	36	109	6.3	18	
	Art. *trid*.	19	153	4.7	25	
	Bal. *sag*.	39	93	5.8	15	

Table 3.--continued

Sand[2] age (yrs.)	Vegetation types and species	Cover (%)	V (%)	SE (%)	SE/$\bar{x}$ (%)	Remarks
400	*Pur*.-*Art*.[3]-(*Prun*.)					Old burn
	Pur. *trid*.	32	102	5.2	16	
	Bal. *sag*.	53	59	5.2	10	
800+	*Pur*.-*Prun*.					Heavily grazed
	Pur. *trid*.	43	100	6.8	16	
	Chry. *visc*.	15	180	4.3	29	
1,000	*Pur*.-*Prun*.					Grazed
	Pur. *trid*.	58	67	6.2	11	
	Ag. *das*.	6	95	0.9	15	
1,300	Burned *Pur*.-*Prun*.					Recent fire
	Chry. *visc*.	22	135	4.8	22	
	Psor. *lan*.	19	137	4.1	22	
	Ag. *das*.	9	116	1.6	18	
1,500+	Burned *Pur*.-*Prun*.					Recent burn
	Psor. *lan*.	24	110	4.2	18	
	Chry. *visc*.	18	120	3.6	20	
	Stip. *com*.	14	103	2.2	16	
1,800	*Art*.-*Pur*.-bunchgrass					Shallow sand, burned
	Art. *trid*.	25	121	4.8	19	
	Pur. *trid*.	10	200	3.2	32	
	Stip. *com*.	20	85	2.8	14	

Table 3.--continued

Sand[2] age (yrs.)	Vegetation types and species	Cover (%)	V (%)	SE (%)	SE/$\bar{x}$ (%)	Remarks
2,100	*Pur*.-bunchgrass					Shallow sand, burned
	Pur. *trid*.	26	148	6.3	24	
	Stip. *com*.	57	46	4.1	7	
2,100	*Pur*.-*Prun*.					Slight disturbance
	Pur. *trid*.	67	54	5.8	9	
	Ag. *das*.	16	58	1.5	9	
4,000+	Old field bunchgrass					Abandoned field
	Stip. *com*.	71	17	1.9	3	
4,500+	*Pur*.-*Prun*.					Slight disturbance
	Pur. *trid*.	55	77	6.8	12	
	Stip. *com*.	14	140	3.1	22	
None	*Art*.-bunchgrass					Native soil, slight disturbance
	Art. *trid*.	23	128	4.8	21	
	Pur. *trid*.	10	244	4.0	40	
	Stip. *com*.	15	92	2.2	15	

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[1] *Prunus* not included

[2] Age of sand from Sample Area III indicated by +

[3] *Artemisia* distribution irregular, data not analyzed

Table 4.--Percentage of shrubs in each height class

Sand age (yrs.)[1]	Vegetation type	Site	Shrubs and height classes (in meters)										
			Pur. trid.			Art. trid.				Prun. dem.			
			.3-	.3-.6	.6+	.3-	.3-.9	.9-1.5	1.5+	.6-	.6-1.2	1.2-1.8	1.8+
80	*Pur*.-*Chry*.	Level	0	20	80	*	*	*	*	*	*	*	*
		Ridge	0	26	74	*	*	*	*	*	*	*	*
150	*Pur*.-*Art*.-(*Prun*.)	Level, old burn	11	78	11	11	19	44	26	*	*	*	*
180	*Pur*.-*Art*.-(*Prun*.)	Level	4	28	68	33	29	38	0	75	25	0	0
		Ridge	0	31	69	*	*	*	*	*	*	*	*
400	*Pur*.-*Art*.-(*Prun*.)	Level	0	21	79	25	50	25	0	70	20	10	0
		Ridge	3	38	59	*	*	*	*	43	57	0	0
800+	*Pur*.-*Prun*.	Level, old burn	4	13	83	*	*	*	*	18	53	18	11
1,000	*Pur*.-*Prun*.	Level, old burn	5	34	61	*	*	*	*	*	*	*	*
1,800	*Art*.-*Pur*.-bunchgrass	Level, old burn	17	83	0	16	84	0	0	*	*	*	*
2,100	*Pur*.-bunchgrass	Level, old burn	12	53	35	*	*	*	*	*	*	*	*
2,100	*Pur*.-*Prun*.	Level, old burn	0	44	56	*	*	*	*	33	67	0	0
4,500+	*Pur*.-*Prun*.	Level, old burn	7	10	83	*	*	*	*	*	*	*	*
None	*Art*.-bunchgrass	Native soil	33	25	42	64	23	13	0	*	*	*	*

[1] Sand age from Sample Area III indicated by +.

* Not in sample.

Table 5.--Ages[1], heights, basal diameters, and growth rates for representative shrubs

Sand age (yrs.)	Site	Purshia tridentata				Prunus demissa				Artemisia tridentata			
		Age (yrs)	Hgt. (M)	Diam. (cm)	Growth (cm/yr)	Age (yrs)	Hgt. (M)	Diam. (cm)	Growth (cm/yr)	Age (yrs)	Hgt. (M)	Diam. (cm)	Growth (cm/yr)
80	Level	35	1.2	6.3	0.18	*				*			
		15	0.5	2.5	0.17								
	Ridge	35	1.4	8.1	0.23	*				*			
150	Level, old burn	13	0.6	1.0	0.08	*				18	1.9	10.2	0.57
										11	1.2	6.1	0.55
180	Level	30	1.4	5.6	0.19	28	2.7	5.6	0.20	20	1.8	11.7	0.58
		20	0.7	2.5	0.12	13	1.2	2.0	0.15	8	0.9	3.6	0.45
		8	0.3	1.0	0.12	9	0.9	1.5	0.17	6	0.4	1.3	0.22
	Ridge	40	1.0	4.6	0.12	16	1.6	4.1	0.26	*			
						7	0.5	1.3	0.19				
400	Level	35	0.4	3.8	0.11	16	1.2	1.5	0.09	25	1.2	6.4	0.26
		34	0.9	6.3	0.19	9	0.7	1.3	0.14	13	0.3	1.0	0.08
										12	0.4	2.0	0.17
	Ridge	22	0.4	2.0	0.09	28	2.0	4.1	0.15	*			
						20	1.0	2.0	0.10				

Table 5.--continued

Sand age (yrs.)	Site	*Purshia tridentata*				*Prunus demissa*				*Artemisia tridentata*			
		Age (yrs)	Hgt. (M)	Diam. (cm)	Growth (cm/yr)	Age (yrs)	Hgt. (M)	Diam. (cm)	Growth (cm/yr)	Age (yrs)	Hgt. (M)	Diam. (cm)	Growth (cm/yr)
800+	Level, old burn	37	0.9	5.6	0.15	18	2.3	4.1	0.23	*			
		33	1.5	5.1	0.15	6	1.3	2.0	0.33				
		17	0.5	2.8	0.16								
1,000	Level, old burn	38	1.3	6.6	0.17	46	3.4	10.1	0.22	*			
1,500	Level, recent burn	16	0.9	2.0	0.12	*				*			
		14	0.2	1.0	0.07								
		12	0.1	0.5	0.04								
1,800	Shallow, old burn	14	0.7	1.5	0.11	*				8	0.7	3.6	0.45
		13	0.7	1.8	0.14					7	0.6	1.5	0.21
2,100	Shallow, old burn	15	0.5	1.5	0.10	*				*			
		12	0.9	1.5	0.12								
		8	0.4	0.5	0.06								
2,100	Level, old burn	46	1.3	7.9	0.17	68	3.0	10.7	0.16	*			
		25	0.6	2.8	0.11	27**	1.0	2.5	0.09				
						23**	0.9	1.8	0.08				

Table 5.--continued

Sand age (yrs.)	Site	Purshia tridentata				Prunus demissa				Artemisia tridentata			
		Age (yrs)	Hgt. (M)	Diam. (cm)	Growth (cm/yr)	Age (yrs)	Hgt. (M)	Diam. (cm)	Growth (cm/yr)	Age (yrs)	Hgt. (M)	Diam. (cm)	Growth (cm/yr)
4,000	Old field	23	0.9	3.0	0.13	*				*			
		5	0.2	0.8	0.16								
		5	0.2	0.5	0.10								
4,500	Level, old burn	35	1.2	7.1	0.20	35	3.4	10.2	0.29	*			
		13	0.4	1.3	0.10	23**	2.4	3.6	0.16				
						10**	1.4	2.3	0.23				
None	Native soil, old burn	40	1.1	4.8	0.12	*				40	1.1	5.6	0.14
		13	0.5	1.5	0.12					30	1.0	4.6	0.15
		10	0.2	0.5	0.05					8	0.5	2.0	0.25

1/ Sand age of sites in Sample Area III indicated by +.

* Not in sample.

** Shrubs hedged by heavy use.

Table 6.--Results of mechanical analysis for sand and native soil, and sand grain sizes as determined by the sieve test

Site	Location	Depth (cm)	Texture class	Separates (percent)			Sand grain sizes (percent)				
				Sand	Silt	Clay	V.fine[1]	Fine	Med.	Coarse	V.coarse
Stabilized sand	Sample Area II	0	Sand	96	1	3	4	40	46	10	0
		30	Sand	97	0	3	Tr	37	52	10	0
		61	Sand	97	0	3	0	30	54	16	0
	Sample Area III	0	Sand	95	2	3	5	75	19	1	0
		30	Sand	97	0	3	2	69	27	2	0
		92	Sand	96	1	3	2	72	24	2	0
Dune	NW Dune Area	0	Sand	95	1	4	7	93	0	0	0
Native soil	Adjacent to NW Dune Area	0	Loamy sand	82	11	7					
		30	Loamy sand	80	12	8					
		46	Sandy loam	75	16	9					
		61	Sandy loam	77	14	9					
		92	Sandy loam	78	13	9					

[1] Includes silt and clay.

Table 7.--Percentages of total moisture during the dry season, moisture held unavailable at a tension of 15 atmospheres, and moisture available to plants

Site	Vegetation	Depth (cm)	Texture class	Tot. H_2O	Unavail. H_2O	Avail. H_2O
Native soil	Sagebrush-bunchgrass	30	Loamy sand	4.8	6.1	0
		61	Sandy loam	5.1	5.9	0
		92	Sandy loam	5.2	7.6	0
Native soil	Sagebrush-bunchgrass	30	Loamy sand	5.3	5.9	0
		61	Sandy loam	4.4	6.0	0
		92	Sand	4.0	4.6	0
Stabilized dune sand	Bitterbrush-chokecherry	30	Sand	1.9	1.2	0.7
		92	Sand	3.2	1.2	2.0
		152	Sand	2.6	1.2	1.4
Active dune sand	Sparse sand ryegrass	30	Sand	2.2	1.2	1.0
		92	Sand	2.7	1.2	1.5
		152	Sand	3.9	1.2	2.7

Table 8.--Organic matter in sands and native soil at a depth of 2.5 to 5.0 cm

Sand age (yrs.)[1]	Site	Organic matter (%)
0	Active dune	0.46
0	Active dune	0.45
150	Level, old burn	7.16
400	Level, undisturbed	3.68
400	Ridge, undisturbed	1.87
800+	Level, old burn	3.20
1,000	Level, old burn	3.18
1,300	Level, recent burn	2.82
1,500+	Level, recent burn	3.32
1,800	Shallow sand, old burn	3.58
2,100	Shallow sand, old burn	3.12
2,100	Level, old burn	3.08
4,000+	Cultivated field	3.27
4,500+	Level, old burn	1.94
None	Native soil	7.01

[1] Age of sand from Sample Area III indicated by +.

LEGEND FOR FIGURES

Figure 1.--Active dunes approaching a stand of big sagebrush. Native soil in the foreground has been covered by wind-deposited sand in advance of the main dune body. The Juniper Buttes appear in the background.

Figure 2.--Map of the study area northeast of St. Anthony, Idaho. Study was concentrated within the three sample areas. The stabilized sand deposits support extensive stands of bitterbrush and chokecherry, important winter browse for deer, elk, and moose.

Figure 3.--Relation of canopy coverage of dominant species to sand age on (A) undisturbed level sand and ridges in Sample Area I, (B) level deep sand sites not recently burned in Sample Areas II and III, and (C) shallow sand and sites disturbed by recent fire and cultivation.

Figure 4.--A typical sparse pioneer stand of sand ryegrass and scurf-pea. The plot frame measures 20 by 50 cm.

Figure 5.--Early successional stages from bare sand at the rear of an active dune in the foreground, to a pioneer sand ryegrass stand, to a rabbitbrush-ryegrass-scurf-pea community (the type is narrower here than in other areas), to a bitterbrush-rabbitbrush stand. Individual rabbitbrush plants are a slightly lighter shade than the bitterbrush. The entire foreground area will be eventually re-covered by the advancing dunes in the background, and the successional process will be repeated.

Figure 6.--Bitterbrush-sagebrush-(chokecherry) community on a sand deposit approximately 150 years old, about 18 years since the most recent fire. Chokecherry was not present in the type here. Sagebrush was very vigorous; the shrub in the right foreground is over 2.4 m tall.

Figure 7.--Bitterbrush-sagebrush-(chokecherry) community on an undisturbed site, showing the high total vegetation cover and diverse speciation. Species prominent in the picture are big sagebrush, bitterbrush, chokecherry (to right of tape), arrow-leaf balsamroot, and needle-and-thread. The tape is 61 cm high.

Figure 8.--Bitterbrush-chokecherry community on old sand near the Big Grassy crater. Grassy openings in the shrub stand, composed mostly of needle-and-thread, are more prominent here than in the same type on younger sand. Light patches in the middle distance are old grassy fields. Juniper Buttes appear in the background.